Claims

1. A method of calculating a twist angle in a wire-like structure in which a twist angle of a sub wire bundle and/or a clamp is calculated with using a computer, the twist angle being produced when the wire-like structure is deformed from a predetermined reference shape to a deformed shape that is different from the reference shape, the wire-like structure including a main wire bundle, the sub wire bundle that branches off from the main wire bundle, and/or the clamp that is attached to the main wire bundle, the method comprising:

a deformed shape model producing step of producing a deformed shape model in which the main wire bundle of the wire-like structure is expressed as a coupled member of a plurality of beam elements so as to correspond to the deformed shape, and a clamp axis corresponding to a rotation axis of the clamp and/or a virtual clamp axis corresponding to a branching direction of the sub wire bundle is added to each of a clamp attachment node and/or sub wire bundle branch node of the main wire bundle;

a reference shape model producing step of producing a reference shape model in which the main wire bundle of the wire-like structure is expressed as a coupled member of a plurality of beam elements so as to correspond to the reference shape, and a predetermined reference axis is added to a clamp attachment node and/or sub wire bundle branch node of the main wire bundle;

a superimposition calculating step of, with using a finite element method, calculating a shape obtained by deforming the reference shape model and superimposing the deformed reference shape model on the deformed

shape model, while referring shape and material properties of the wire-like structure; and

a twist angle calculating step of, after the superimposition calculating step, calculating an angle formed by the reference axis, and the clamp axis and/or the virtual clamp axis, as the twist angle.

2. The method of calculating a twist angle in a wire-like structure according to claim 1, in order to calculate the virtual clamp axis, further comprising:

a tangent plane producing step of producing a tangent plane which contains both a tangent vector with respect to the sub wire bundle, and a tangent vector with respect to the main wire bundle, the tangent vectors starting at the sub wire bundle branch node; and

a virtual clamp axis calculating step of calculating a vector as the virtual clamp axis, the vector starting in the tangent plane at the sub wire bundle branch node and being perpendicular to the tangent vector with respect to the main wire bundle.

3. The method of calculating a twist angle in a wire-like structure according to claim 2, further comprising:

a displaying step of displaying the clamp axis and/or the virtual clamp axis together with the reference shape model, while returning by a degree corresponding to the twist angle.

4. The method of calculating a twist angle in a wire-like structure

according to any one of claims 1 to 3, wherein

the reference shape corresponds to a shape obtained when the wire-like structure is developed on a jig plate; and

the deformed shape corresponds to a shape obtained when the wire-like structure is attached to a predetermined portion.

5. A method of calculating a twist angle in a wire-like structure in which twist angles of sub wire bundles are calculated with using a computer, the twist angles being produced when a wire-like structure is deformed to a predetermined shape, the wire-like structure being designed so as to be laid in a predetermined portion, and including a main wire bundle and the sub wire bundles that branch off from the main wire bundle, the method comprising:

a finite element model producing step of producing a finite element model of the wire-like structure while assuming that the wire-like structure is an elastic body in which a plurality of beam elements are coupled together;

a deforming step of deforming the wire-like structure to a reference shape in which the main wire bundle exists in a predetermined plane, by applying shape and material properties and restraint conditions of the wire-like structure to the finite element model; and

a twist angle calculating step of calculating angles which are formed by the sub wire bundles with respect to the plane, as the twist angles.

6. The method of calculating a twist angle in a wire-like structure according to claim 5, wherein the restraint conditions corresponding to the reference shape are set so that the main wire bundle is linearly stretched

without being twisted.

7. The method of calculating a twist angle in a wire-like structure according to claim 5 or 6, wherein the plane is a reference plane in which a jig plate that is to be used in production of the wire-like structure is supposed.

8. The method of calculating a twist angle in a wire-like structure according to claim 7, wherein the main wire bundle has a largest diameter among all wire bundles constituting the wire-like structure.

9. The method of calculating a twist angle in a wire-like structure according to claim 8, wherein the restraint conditions are set so that a wire bundle which, among the sub wire bundles, is next in thickness to the main wire bundle exists in the reference plane.

10. The method of calculating a twist angle in a wire-like structure according to claim 5, wherein

the wire-like structure includes a clamp which is attached to the main wire bundle, and which can produce a twist; and

an angle which is formed by a rotation axis of the clamp with respect to the plane is calculated as the twist angle.

11. The method of calculating a twist angle in a wire-like structure according to claim 5, wherein

the wire-like structure includes, in place of the sub wire bundles, a

clamp which is attached to the main wire bundle, and which can produce a twist; and

an angle which is formed by a rotation axis of the clamp, in place of the sub wire bundles, with respect to the plane is calculated as the twist angle.

12. An apparatus for calculating a twist angle in a wire-like structure in which a twist state of a sub wire bundle and/or a clamp is calculated, the twist angle being produced when the wire-like structure is deformed from a predetermined reference shape to a deformed shape that is different from the reference shape, the wire-like structure including a main wire bundle, the sub wire bundle that branches off from the main wire bundle, and/or the clamp that is attached to the main wire bundle, the apparatus comprising:

a deformed shape model producing unit that produces a deformed shape model in which the main wire bundle of the wire-like structure is expressed as a coupled member of a plurality of beam elements so as to correspond to the deformed shape, and a clamp axis corresponding to a rotation axis of the clamp and/or a virtual clamp axis corresponding to a branching direction of the sub wire bundle is added to each of a clamp attachment node and/or sub wire bundle branch node of the main wire bundle;

a reference shape model producing unit that produces a reference shape model in which the main wire bundle of the wire-like structure is expressed as a coupled member of a plurality of beam elements so as to correspond to the reference shape, and a predetermined reference axis is added to a clamp attachment node and/or sub wire bundle branch node of the main wire bundle;

a superimposition calculating unit that calculates a shape obtained by deforming the reference shape model and superimposing the deformed reference shape model on the deformed shape model, with using a finite element method, while referring shape and material properties of the wire-like structure; and

a twist angle calculating unit that calculates an angle formed by the reference axis, and the clamp axis and/or the virtual clamp axis, as the twist angle, after calculation by the superimposition calculating unit.

13. The program for calculating a twist angle in a wire-like structure wherein, in order to calculate a twist state of a sub wire bundle and/or a clamp, the twist angle being produced when the wire-like structure is deformed from a predetermined reference shape to a deformed shape that is different from the reference shape, the wire-like structure including: a main wire bundle; the sub wire bundle that branches off from the main wire bundle; and/or the clamp that is attached to the main wire bundle, the program causes a computer to function as:

a deformed shape model producing unit that produces a deformed shape model in which the main wire bundle of the wire-like structure is expressed as a coupled member of a plurality of beam elements so as to correspond to the deformed shape, and a clamp axis corresponding to a rotation axis of the clamp and/or a virtual clamp axis corresponding to a branching direction of the sub wire bundle is added to each of a clamp attachment node and/or sub wire bundle branch node of the main wire bundle;

a reference shape model producing unit that produces a reference

shape model in which the main wire bundle of the wire-like structure is expressed as a coupled member of a plurality of beam elements so as to correspond to the reference shape, and a predetermined reference axis is added to a clamp attachment node and/or sub wire bundle branch node of the main wire bundle;

a superimposition calculating unit that calculates a shape obtained by deforming the reference shape model and superimposing the deformed reference shape model on the deformed shape model, with using a finite element method, while referring shape and material properties of the wire-like structure; and

a twist angle calculating unit that calculates an angle formed by the reference axis, and the clamp axis and/or the virtual clamp axis, as the twist angle, after calculation by the superimposition calculating unit.

14. A method of calculating a twist angle in a wire-like structure in which a twist angle of a clamp attached to a sub wire member that branches off from a main wire member, as viewed from a side of the main wire member is calculated with using a computer, the method comprising:

a main wire member deformed shape model producing step of producing a main wire member deformed shape model in which a deformed shape of the main wire member is expressed as a coupled member of a plurality of beam elements, and a branch axis for obtaining a twist angle of the sub wire member is added to a wire member branch node on the main wire member;

a main wire member reference shape model producing step of

producing a main wire member reference shape model in which the main wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a main wire member reference shape that is a shape obtained by straightly stretching the main wire member without being twisted, and a first reference axis which functions as a reference for obtaining a twist angle of the branch axis is added to a position corresponding to the wire member branch node;

a main wire member angle calculating step of, with using a finite element method, calculating a first twist angle while referring physical properties of the wire-like structure, the first twist angle being an angle which is formed by the first reference axis and the branch axis when the main wire member reference shape model is deformed and then superimposed on the main wire member deformed shape model;

a sub wire member deformed shape model producing step of producing a sub wire member deformed shape model in which a deformed shape of the sub wire member is expressed as a coupled member of a plurality of beam elements, and a clamp axis for obtaining a twist angle of the clamp is added to a clamp attachment node on the sub wire member;

a sub wire member reference shape model producing step of producing a sub wire member reference shape model in which the sub wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a sub wire member reference shape that is a shape obtained by straightly stretching the sub wire member without being twisted, and a second reference axis which functions as a reference for obtaining a twist angle of the clamp axis is added to a position corresponding to the clamp axis;

a sub wire member angle calculating step of, with using a finite element method, calculating a second twist angle while referring physical properties of the wire-like structure, the second twist angle being an angle which is formed by the second reference axis and the clamp axis when the sub wire member reference shape model is deformed and then superimposed on the sub wire member deformed shape model; and

a twist angle calculating step of correcting the second twist angle on the basis of the first twist angle to obtain an angle formed by the first reference axis and the clamp axis.

15. A method of calculating a twist angle in a wire-like structure in which a twist angle of a second sub wire member branching off from a sub wire member that branches off from a main wire member, as viewed from a side of the main wire member is calculated with using a computer, the method comprising:

a main wire member deformed shape model producing step of producing a main wire member deformed shape model in which a deformed shape of the main wire member is expressed as a coupled member of a plurality of beam elements, and a first branch axis for obtaining a twist angle of the sub wire member is added to a wire member branch node on the main wire member;

a main wire member reference shape model producing step of producing a main wire member reference shape model in which the main wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a main wire member reference shape that is a shape obtained by straightly stretching the main wire member without being twisted,

and a first reference axis which functions as a reference for obtaining a twist angle of the first branch axis is added to a position corresponding to the wire member branch node;

a main wire member angle calculating step of, with using a finite element method, calculating a first twist angle while referring physical properties of the wire-like structure, the first twist angle being an angle which is formed by the first reference axis and the first branch axis when the main wire member reference shape model is deformed and then superimposed on the main wire member deformed shape model;

a sub wire member deformed shape model producing step of producing a sub wire member deformed shape model in which a deformed shape of the sub wire member is expressed as a coupled member of a plurality of beam elements, and a second branch axis for obtaining a twist angle of the second sub wire member is added to a second wire member branch node on the sub wire member;

a sub wire member reference shape model producing step of producing a sub wire member reference shape model in which the sub wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a sub wire member reference shape that is a shape obtained by straightly stretching the sub wire member without being twisted, and a second reference axis which functions as a reference for obtaining a twist angle of the second branch axis is added to a position corresponding to the second wire member branch node;

a main wire member angle calculating step of, with using a finite element method, calculating a second twist angle while referring physical

properties of the wire-like structure, the second twist angle being an angle which is formed by the second reference axis and the second branch axis when the sub wire member reference shape model is deformed and then superimposed on the sub wire member deformed shape model; and

a twist angle calculating step of correcting the second twist angle on the basis of the first twist angle to obtain an angle formed by the first reference axis and the second branch axis.

16. An apparatus for calculating a twist angle in a wire-like structure in which a twist angle of a clamp attached to a sub wire member that branches off from a main wire member, as viewed from a side of the main wire member is calculated with using a computer, the apparatus comprising:

a main wire member deformed shape model producing unit that produces a main wire member deformed shape model in which a deformed shape of the main wire member is expressed as a coupled member of a plurality of beam elements, and a branch axis for obtaining a twist angle of the sub wire member is added to a wire member branch node on the main wire member;

a main wire member reference shape model producing unit that produces a main wire member reference shape model in which the main wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a main wire member reference shape that is a shape obtained by straightly stretching the main wire member without being twisted, and a first reference axis which functions as a reference for obtaining a twist angle of the branch axis is added to a position corresponding to the wire

member branch node;

a main wire member angle calculating unit that calculates a first twist angle while referring physical properties of the wire-like structure, with using a finite element method, the first twist angle being an angle which is formed by the first reference axis and the branch axis when the main wire member reference shape model is deformed and then superimposed on the main wire member deformed shape model;

a sub wire member deformed shape model producing unit that produces a sub wire member deformed shape model in which a deformed shape of the sub wire member is expressed as a coupled member of a plurality of beam elements, and a clamp axis for obtaining a twist angle of the clamp is added to a clamp attachment node on the sub wire member;

a sub wire member reference shape model producing unit that produces a sub wire member reference shape model in which the sub wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a sub wire member reference shape that is a shape obtained by straightly stretching the sub wire member without being twisted, and a second reference axis which functions as a reference for obtaining a twist angle of the clamp axis is added to a position corresponding to the clamp axis;

a sub wire member angle calculating unit that calculates a second twist angle while referring physical properties of the wire-like structure, with using a finite element method, the second twist angle being an angle which is formed by the second reference axis and the clamp axis when the sub wire member reference shape model is deformed and then superimposed on the sub wire member deformed shape model; and

a twist angle calculating unit that corrects the second twist angle on the basis of the first twist angle to obtain an angle formed by the first reference axis and the clamp axis.

17. A program for calculating a twist angle in a wire-like structure wherein, in order to calculate a twist angle of a clamp attached to a sub wire member that branches off from a main wire member, as viewed from a side of the main wire member, the program causes a computer to function as:

a main wire member deformed shape model producing unit that produces a main wire member deformed shape model in which a deformed shape of the main wire member is expressed as a coupled member of a plurality of beam elements, and a branch axis for obtaining a twist angle of the sub wire member is added to a wire member branch node on the main wire member;

a main wire member reference shape model producing unit that produces a main wire member reference shape model in which the main wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a main wire member reference shape that is a shape obtained by straightly stretching the main wire member without being twisted, and a first reference axis which functions as a reference for obtaining a twist angle of the branch axis is added to a position corresponding to the wire member branch node;

a main wire member angle calculating unit that calculates a first twist angle while referring physical properties of the wire-like structure, with using a finite element method, the first twist angle being an angle which is formed by

the first reference axis and the branch axis when the main wire member reference shape model is deformed and then superimposed on the main wire member deformed shape model;

a sub wire member deformed shape model producing unit that produces a sub wire member deformed shape model in which a deformed shape of the sub wire member is expressed as a coupled member of a plurality of beam elements, and a clamp axis for obtaining a twist angle of the clamp is added to a clamp attachment node on the sub wire member;

a sub wire member reference shape model producing unit that produces a sub wire member reference shape model in which the sub wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a sub wire member reference shape that is a shape obtained by straightly stretching the sub wire member without being twisted, and a second reference axis which functions as a reference for obtaining a twist angle of the clamp axis is added to a position corresponding to the clamp axis;

a sub wire member angle calculating unit that calculates a second twist angle while referring physical properties of the wire-like structure, with using a finite element method, the second twist angle being an angle which is formed by the second reference axis and the clamp axis when the sub wire member reference shape model is deformed and then superimposed on the sub wire member deformed shape model; and

a twist angle calculating unit that corrects the second twist angle on the basis of the first twist angle to obtain an angle formed by the first reference axis and the clamp axis.

18. A method of calculating a twist angle in a wire-like structure in which a twist angle of a clamp attached to a main wire member, with respect to a twist-free plane is calculated with using a computer, and then displayed, the method comprising:

a main wire member deformed shape model producing step of producing a main wire member deformed shape model in which a deformed shape of the main wire member is expressed as a coupled member of a plurality of beam elements, and a clamp axis for expressing a twist angle of the clamp is added to a clamp attachment node on the main wire member;

a main wire member reference shape model producing step of producing a main wire member reference shape model in which the main wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a main wire member reference shape that is a shape obtained by straightly stretching the main wire member without being twisted, and reference axes for obtaining the twist-free plane are added to nodes including a position corresponding to the clamp attachment node, respectively;

a twist-free plane setting step of setting the twist-free plane by connecting together the reference axes when the main wire member reference shape model is deformed and then superimposed on the main wire member deformed shape model; and

a displaying step of displaying the twist-free plane together with the deformed shape and the clamp axis.

19. The method of calculating a twist angle in a wire-like structure according to claim 18, wherein the method includes a second displaying step of

displaying the twist-free plane together with the deformed shape, in place of the displaying step.

20. A method of calculating a twist angle in a wire-like structure in which twist angles of clamps attached to a main wire member and a sub wire member that branches off from the main wire member, with respect to a twist-free plane are calculated with using a computer, and then displayed, the method comprising:

a main wire member deformed shape model producing step of producing a main wire member deformed shape model in which a deformed shape of the main wire member is expressed as a coupled member of a plurality of beam elements, and a first clamp axis for expressing a twist angle of a clamp on the main wire member is added to a clamp attachment node on the main wire member;

a main wire member reference shape model producing step of producing a main wire member reference shape model in which the main wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a main wire member reference shape that is a shape obtained by straightly stretching the main wire member without being twisted, and first reference axes for obtaining a first twist-free plane are added to nodes including a position corresponding to the clamp attachment node, respectively;

a first twist-free plane setting step of setting the first twist-free plane by connecting together the first reference axes when the main wire member reference shape model is deformed and then superimposed on the main wire member deformed shape model;

a sub wire member deformed shape model producing step of producing a sub wire member deformed shape model in which a deformed shape of the sub wire member is expressed as a coupled member of a plurality of beam elements, and a second clamp axis for expressing a twist angle of a clamp on the sub wire member is added to a clamp attachment node on the sub wire member;

a sub wire member reference shape model producing step of producing a sub wire member reference shape model in which the sub wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a sub wire member reference shape that is a shape obtained by straightly stretching the sub wire member without being twisted, and second reference axes for obtaining a second twist-free plane are added to nodes including a position corresponding to the clamp attachment node, respectively;

a second twist-free plane setting step of setting the second twist-free plane by connecting together the second reference axes when twists of the first reference axes constituting the first twist-free plane are propagated to the second reference axes, and the sub wire member reference shape model is deformed and then superimposed on the sub wire member deformed shape model; and

a displaying step of displaying the first twist-free plane and the second twist-free plane together with the deformed shape, the first clamp axis, and the second clamp axis.

21. An apparatus for calculating a twist angle in a wire-like structure in

which a twist angle of a clamp attached to a main wire member, with respect to a twist-free plane is calculated with using a computer, and then displayed, wherein the apparatus comprising:

a main wire member deformed shape model producing unit that produces a main wire member deformed shape model in which a deformed shape of the main wire member is expressed as a coupled member of a plurality of beam elements, and a clamp axis for expressing a twist angle of the clamp is added to a clamp attachment node on the main wire member;

a main wire member reference shape model producing unit that produces a main wire member reference shape model in which the main wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a main wire member reference shape that is a shape obtained by straightly stretching the main wire member without being twisted, and reference axes for obtaining the twist-free plane are added to nodes including a position corresponding to the clamp attachment node, respectively;

a twist-free plane setting unit that sets the twist-free plane by connecting together the reference axes when the main wire member reference shape model is deformed and then superimposed on the main wire member deformed shape model; and

a displaying unit that displays the twist-free plane together with the deformed shape and the clamp axis.

22. A program for calculating a twist angle in a wire-like structure wherein, in order to calculate and display a twist angle of a clamp attached to a main wire member, the program causes a computer to function as:

a main wire member deformed shape model producing unit that produces a main wire member deformed shape model in which a deformed shape of the main wire member is expressed as a coupled member of a plurality of beam elements, and a clamp axis for expressing a twist angle of the clamp is added to a clamp attachment node on the main wire member;

a main wire member reference shape model producing unit that produces a main wire member reference shape model in which the main wire member is expressed as a coupled member of a plurality of beam elements so as to correspond to a main wire member reference shape that is a shape obtained by straightly stretching the main wire member without being twisted, and reference axes for obtaining the twist-free plane are added to nodes including a position corresponding to the clamp attachment node, respectively;

a twist-free plane setting unit that sets the twist-free plane by connecting together the reference axes when the main wire member reference shape model is deformed and then superimposed on the main wire member deformed shape model; and

a displaying unit that displays the twist-free plane together with the deformed shape and the clamp axis.